A STUDY OF GREEN SYNTHESIZED LANTHENIDES-DOPED SPINEL FERRITE (MFe_2O_4) NANOPARTICLES FOR PHOTOCATALYTIC AND ANTIOXIDANT ACTIVITIES

SYNOPSIS

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1. Introduction

1.1 Nanotechnology

Any technology on the nanoscale that has various applications in the real world is called Nanotechnology. Nanotechnology factually covers the manufacturing and application of physical, chemical and biological systems at nanoscales ranging from individual molecules or atoms less than 100 nm. The concept of nanotechnology is commonly credited to the physicist and the famous Nobel Laureate Dr. Richard P. Feynman. His classic science lectures were entitled “There's Plenty of Room at the Bottom: An Invitation to Enter a New Field of Physics”. Nano technology has the capability to resolve global issues as it has potential to change our perceptions and expectations (Nasrollahzadeh et al., 2019). Nano technology defines the science and technology related to the control and handling of matter and devices in the range 1-100 nm (one billionth of a matter).Materials shows unique chemical, physical and biological properties in this range due to high surface-area- to-volume ratio and quantum mechanical effects. Fields such as applied physics, materials science, chemistry, biology, biomedical engineering, surface science, electrical engineering and robotics are involved in nanotechnology. Two approaches are mainly used in nanotechnology. These are known as the “bottom-up” and “top-down” approaches. The bottom up involves building up from atom sin to molecules to assemble nanostructures, material and devices. The “top-down” approach involves making structures and devices from larger entities without specific control at the atomic level. In the recent years progress in both approaches has been accelerated with the development of highly sensitive instruments. Research is being carried out worldwide to understand the advantages and limitations of nanotechnology and its applications in a wide range of disciplines from material science, biomedical research to space research (Subramani et al., 2019).

1.2Nanoparticles

A discretentity that has dimensions of the order of 100 nm or less is called nanoparticle. (Laborda et al., 2023). Unique features of nanoparticles are attributed due to this small size and surface structure. The variations in physical properties lead to enhance versatility and efficiency in product development that result in its effective applications in industrial, environmental and medical areas. Optical properties of nanoparticles are reported to be dependent on the size, which imparts different colours due to absorption in the visible

region. In nanoscale range different physical and chemical properties of material changes dramatically due to their small size and high surface to volume ratio. So, in order to provide new properties to the materials it might be nanostructured for the changes linked specifically to size and structure. Performance of any application increases efficiently with nanoparticles as compared with bulk materials (Ahmeda et al., 2017).Among the various types of nanoparticles, ferrite nanoparticles have significance importance because of their magnetic properties. Especially ferrite nanoparticles with spinel structure that imparts super paramagnetic behavior make them highly suitable for biomedical, environmental and electronic applications.

1.3 Ferrite

Ferrites are homogeneous ceramic materials composed of various oxides containing iron oxide as their major constituent. Ferrites are hard, brittle, iron-containing, and generally gray or black and are made up of a large number of small crystals. They are made up of iron oxide and one or more other metals in chemical combination by the reaction of ferric oxide with any of a number of other metals, including magnesium, aluminum barium, manganese, copper, nickel, cobalt, or even iron itself. Due to their unique magnetic properties extensive research has been performed on the synthesis and applications of magnetically recoverable ferromagnetic materials derived from iron oxide as magnetite Fe_3O_4 or hematite Fe_2O_3. There are many synthesis methods to obtain Ferrites in three different crystal systems. Ferrites cannot be substituted by ferromagnetic metals as they are electrically non-conductive so restrict this area of application, meaning that they are insulators and ferromagnetic means that they can be magnetized and get attracted by a magnet. LA naturally occurring form of iron oxide is Lodestone or magnetite i.e. ferrite by both engineers and geologist. This gives them an advantage over nickel, iron, and other transition metals that already have magnetic properties (“ferromagnetic”) for many applications because these metals also conduct electricity (shaikh et al., 2020).Ferrites can be divided into two families based on their resistance to being demagnetized (magnetic coercivity).

1.4 Classification of ferrites

Ferrites are classified into two categories, based on their magnetic coercivity and the resistance to get demagnetized i.e, soft and hard ferrites.

1.4.1 Hardferrites

Hard ferrites have high coercivity, so are difficult to demagnetize. Hard ferrites are also knownaspermanentmagneticmaterialsbecausetheycanholdtheirmagnetismafter

being magnetized. Hard ferrites are those ferromagnetic materials which have gradually rising magnetization curve, large hysteresis loop and large energy losses during magnetization. Hard ferrites can be produced by heating and sudden cooling and cannotbe easily magnetized and demagnetized. Hard ferrites are compound of iron and barium or strontium oxides. Hard ferrites have high saturation flux density, low susceptibility and permeability, high eddy current losses, and high retentivity and coercivity. They are used to make permanent magnets for applications such as refrigerator magnets, loudspeakers, and small electric motor.

1.4.2 Soft ferrites

Soft ferrites have low coercivity, so they easily change their magnetization and act as conductors of magnetic fields. Soft ferrites are the ferrimagnetic materials that do not hold their magnetism after being magnetized. Soft ferrites have a steeply rising magnetisation curve, narrow and small hysteresis loop, and small energy losses during magnetisation. These materials can be produced by heating and slow cooling and can easily be magnetized and demagnetized. Soft ferrites are ceramic insulators with cubic crystal structure MFe_2O_4, where M is transition metal ions, such as Ni, Mn, Zn, etc. Soft ferrites have high values of susceptibility and permeability, low eddy current losses, and low retentivity and coercivity. Therefore, soft ferrites are used in electromagnets, computer data storage, cores of transformer, telephone signal transmitters and receiver,etc (Vedrtnam et al., 2020).

1.5 Structural features of ferrites

Ferrites are categorized based on their magnetic behaviour and crystal structures. These are spinel ferrites (MFe_2O_4, where M is usually a transition metal such as Fe, Mn, Zn, Co, Co, Ni, etc.), garnet ferrites ($RE_3Fe_5O_{12}$, where RE stands for rare earth cations), hexa ferrites or hexagonal ferrites (the most popular type being M-type with the formula $MFe_{12}O_{19}$ where M is usually Ba^{2+} or Sr^{2+}) and orthoferrites ($MFeO_3$) (Almessiere et al., 2021). We will focus on nanoparticles of spinel ferrites only. Spinel ferrites are magnetic materials that exhibit a number of interesting applications. They possess a high electrical resistivity and low magnetic loss and thereby, are magnetically soft. Spinel ferrites are characterized by a formula MFe_2O_4, where M stands for divalent metal ions such as Cu, Ni ,Mg, Mn, Co, Zn, Cd, etc. Spinel ferrite crystallizes in the cubic structure. The spinel lattice is composed of lose-packed oxygen an ions

arrangement in which thirty-two oxygen ions form unit cell. These anions are packed in a face-centered cubic. Spinel compounds can be classified as normal, inverse, and mixed based on the distribution of cations over the crystallographic sites with in crystal. $ZnFe_2O_4$ is a common spinel ferrite. Some oxides of aluminum and chromium ($MA_{l2}O_4$ and MCr_2O_4 where M can be Mg^{2+}, Fe^{2+}, Co^{2+}, and Zn^{2+}) also adopt the normal spinel structure. In inverse spinel ferrites, half of the tetrahedral positions are filled with the trivalent cations. The rest of the tetrahedral interstices is composed of the divalent cations and the octahedral sites are filled with trivalent cation. This is shown by most of the ferrites of the first transition metal series such as maghemite, magnetite, $CoFe_2O_4$, and $CuFeO_4$ (Almessiere et al., 2021). Hexaferrites are hexagonal or rhombohedral ferromagnetic oxides with formula $MFe_{12}O_{19}$,where M is an element like Barium, calcium, Leador Strontium. In these types of ferrites, oxygen ions have closed packed hexagonal crystal structure. They are used at very high frequency. The structure and lattice of hexagonal ferrites is very similar to the spinel structure with closely packed oxygen ions, but there are also metal ions at some layers with the same ionic radii as that of oxygen ions. Hexagonal ferrites have larger ions than that of garnet ferrite and are formed by the replacement of oxygen ions. Most of these larger ions are barium, strontium or lead. Hexaferrites crystal structure have preferred direction of magnetization when placed in a magnetic field, giving them an Magneto crystalline anisotropy MCA, which is often parallel to the c-axis, coming out of the basal plane of the hexagonal crystal (Tolani et al., 2019).

1.6 Green synthesis of ferrite nanoparticles.

Metal ferrite nanoparticles will be synthesized by taking different types of plant extract from local areas. Different plants are used to cure many type so diseases like treatment of bronchial catarrh, enuresis, cystitis, psoriasis, uterine carcinomas, amenorrhea, rheumatism, asthma, skin infections, mumps, bacterial dysentery, arthritic pains and premature blandness. Different parts of plant like *THUJA* are exhibited extensively biological activities like hair growth-promoting, antiviral, antiallergic, anti-espileptic, anti-inflammatory, antibacterial, antioxidant, and antifungal activities. Apart of these effects, it can be used as nematicidal, insecticidal and molluscicidal activity against various pests (Jain et al., 2017).

1.7 Doping

Doping nanomaterials provides a flexible way to tune to the properties of the materials while maintaining their high surface areas. The electronic, optical, photochemical, photoelectron chemical, photocatalytic and photoexcited relaxation properties can be tuned towards the desired direction by doping different elements. Doping, through the incorporation of specific entities such as individual ions into nanostructures, has been identified as an avenue for the enhancement of their properties. In the doping process, the selection of suitable dopants and their entrapped quantity are key factors that are required for the desired application. The limitations for use associated with nanomaterial properties can be mitigated by adopting doping as a method for the development of desired properties for both crop protection and improvement. Unlike the fields of electronics, energy, and medicine, the agriculture sector has yet to explore the full potential of these types of nanoscale materials (Rani et al. 2023).

2. Literature review

(Jadhav et al., 2023) studied that in preparing$Zn_{0.5}Ni_{0.3}Cu_{0.2}Fe_{2-x}Gd_xO_4$ (x= 0, 0.025, 0.05, 0.075, 0.1) using self-ignition series of Gd^{3+}-doped mixed Ni–Cu–Zn ferrites with composition of sol–gel method. The prepared nanoparticles with an average size ranging from 22 to 26 nm show a single-phase cubic structure belonging to the spinel matrix. A rise in the Gd^{3+}concentration leads to an increase in crystallite size and lattice parameter. In Fourier transform infrared spectra, two main absorption bands belonging to the spinel structure are observed. The high-frequency bands (υ_1) represent the tetrahedral complex, while the low-frequency bands (υ_2) signify the octahedral complex. The magnetic characteristics of the material, such as saturation magnetization and coercivity are significantly altered with the concentration of Gd^{3+}in the solution. Using Rhodamine B (RhB) as a model organic pollutant, an in-depth investigation of the photocatalytic activity show that adding an adequate amount of Gd^{3+}significantly enhances the number of hydroxyl radicals produced bythe ferrite, in turn, increasing the photocatalytic activity of the material.

(Rabaa et al., 2023) has studied in the paper titled as “Influence of Lanthanum Doping on the Photocatalytic and Antibacterial Capacities of $Mg_{0.33}Ni_{0.33}Co_{0.33}Fe_2O_4$Nanoparticles "$Mg_{0.33}Ni_{0.33}Co_{0.33}La_xFe_{2-x}O_4$Nanoparticles where $0.00 \leq x \leq 0.08$ were successively synthesized by the co-precipitation method. As x increases, band gap energy increases from 2.92 to 3.25eV. Doping $Mg_{0.33}Ni_{0.33}Co_{0.33}La_xFe_{2-x}O_4$ Nanoparticles with La

enhanced their photocatalytic performance. Among the prepared Nanoparticles, enhanced photocatalytic activity was exhibited by Nanoparticles where x = 0.01. This was attributed to the slow recombination rate of the electron-hole pair, as revealed by PL analysis. Among the tested Nanoparticles, the$Mg_{0.33}Ni_{0.33}Co_{0.33}La_{0.00}Fe_2O_4$Nanoparticles had antibacterial activity. An antibiofilm action was observed for some of the doped Nanoparticles, especially those where x = 0.01, 0.02 and 0.04, mainly against biofilms of Gram-positive bacteria. Due to their high antibiofilm activity, the $Mg_{0.33}Ni_{0.33}Co_{0.33}La_{0.00}Fe_{2-x}O_4$Nanoparticles are applicable in the biomedical field, especially against bacterial pathogens.

(Elayakumar.,2019)has studied in "Structural, morphological, enhance dmagnetic properties and antibacterial bio-medical activity of rare earth element (REE) cerium (Ce^{3+}) doped $CoFe_2O_4$nanoparticles" that Cerium (Ce^{3+}) doped cobalt ferrite ($CoFe_2O_4$) nanoparticles were prepared by the simple sol-gel combustion technique. Cerium was successfully substituted into the spinel lattice without any distortion. There was decrease in the crystallite size on doping with Ce^{3+}. The decrease in the saturation magnetization (M_s, emu/g) with the increase in Ce^{3+}content rendered the synthesized sample applicable in field of antenna construction. This change will be also suitable for reducing the size of the antenna. The antibacterial activity of Ce^{3+}doped $CoFe_2O_4$nanoparticles was found to be enhanced with increase in Ce^{3+} doping level as it causes a reduction in the grain size. (Bharti et al., 2021) has worked on the samples with composition as $Mn_{0.4}Zn_{0.6}Cd_{0.2}La_xFe_{1.8-x}O_4(0.0\leq x\leq 0.4)$were prepared using the conventional co-precipitation route. The analysis of XRD patterns revealed the formation of spinel structure along with the presence of a secondary $LaFeO_3$ phase at the grain boundaries with increasing La content in the composition.

(F.S Mustafa 2023) has studied that Mg-doped $Zn_{0.5}Ni_{0.5}Fe_2O_4$ (Mg–FZN) as a photocatalyst was synthesised using a simple co-precipitation-doping technique to develop a dual-function material with the ability to degrade hazardous and refractory pollutants and inactivate bacterial strains. The characterization results revealed that Mg-FZN is an *n*-type semiconductor with a conduction band of −0.413eV, an average pore width of 2.32nm, and a crystal size of 31.45 nm. The photocatalytic activity of Mg-FZN was assessed based on the degradation of 2,4,5-trichlorophenol and achieved 83.8% degradation efficiency under optimised conditions. Within 60min, 25mg of Mg–FZN had bactericidal effects on the bacteria *E. coli* and*S. aureus*in both the presence and absence of UV light.

(Rajivgandhi et al., 2021) highlighted in their work on "Effect of Ti and Cu doping on the structural, optical, morphological and anti-bacterial properties of nickel ferrite nanoparticles" used sol-gel to synthesize the Nanoparticles. The prepared nanoparticles were characterized using XRD, SEM and UV to identify the structure, morphology and optical property. All the three samples exhibited a single-phase nickel ferrite structure at size of 31 to 23nm. Morphology of the nickel ferrite nanoparticles remained the same even after the addition of titanium and copper but, slight variations were observed in the morphology of the samples with the addition of Ti and Cu. The FTIR analysis of the bare and doped nickel ferrite nanoparticles revealed the vibrational stretching modes M-O present at 580 $cm^{-1}$and 387cm^{-1}. The optical absorption of the Ti and Cu substituted nanoparticles increased which, resulted in the narrowing of band gap energy**.** The enhanced antibacterial activity was observed for Cu doped nickel ferrite nanoparticles. This enhancement in antibacterial activity was due to the crystallinity, morphology, band gap and the dopant.

(Rahmawati et al., 2023) has studied on lanthanum doped copper ferrite synthesized by co-precipitation method and annealed at different temperatures at 200°C,300°C and 400°C for 5 hours depicted that the produced nanoparticle sample indicates a single phase of fcc inverse spinel phase. The crystallite size (D) calculation at the strongest peaks shows the increase in enhancing the annealing temperature i.e., 18.99 nm, 19.90 nm, and 23.21 nm for 200 °C, 300 °C, and 400 °C, respectively. The FTIR results showed absorption band at the tetrahedral site, v_1 ~575 cm^{-1} and the octahedral site, v_2 ~474 cm^{-1}. The absorption bands indicate that the lanthanum ions have successfully replaced the Fe^{3+}cations in the original cobalt ferrite structure. According to the hysteresis loop, the coercive field's (H_C) magnitude falls from 700 Oe down to 550 Oe as $T_a$increases. This result is consistent with the an isotropy constant which decreased from 0.77×10^4 erg/cm^3 to 0.56×10^4erg/cm^3. The obtained nanoparticles also showed superior performance (much larger than 95%) for dye removal of Congo red.

3. Research Gap Identification

In fact, many researchers have studied synthesis of Fe_2O_4 and doped Fe_2O_4 Nanoparticles by using different types of transition elements but there is very less literature on the synthesis of Lanthanides-doped Fe_2O_4 Nanoparticles by using transition elements as well as*T.orientalis* at particular temperature. The present study will discuss the comparative

physical and chemical properties of green synthesized (Yb, Gd, Nb, Er) doped MFe_2O_4(M=Mg, Cu, Zn, Ti, Si, Ni, Mn, Co) ferrites nanoparticles. In addition to this, synthesized Nanoparticles will be used for the photocatalytic and antioxidant activity.

4. Objectives

After going through different literature discussion, the objectives of present research are as follows:

I. To study the green synthesis of lanthanides doped MFe_2O_4 ferrite nanoparticles by Co-precipitation method.
II. To characterize the different characterization techniques.
III. To study the photocatalytic and antioxidant activity of synthesized nanoparticles.

5. ProposedMethodology

5.1 Materials

Ferric Nitrate nonahydrate $Fe(NO_3)_3.9H_2O$ (98 %, Sigma Aldrich), Magnisium nitrate hexahydrate (98.5 %, Emplura), Ytterbium Chloride hexahydrate (97 %, Emplura), Copper(II) Nitrate trihydrate(98.5 %, Emplura), Zinc acetatedihydrate (98 %, Emplura), Sodium hydroxide (98 %, Emplura) and distilled water. Plant leaves of *Thuja* will be collected from local areas of Dharamshala District Kangra, Himachal Pradesh for the preparation of extract.

5.2 Procedure of plant extract

The fresh leaves of plant will be collected from local areas of Hamirpur, Himachal Pradesh. The collected leaves will be washed properly with tap water and then with distilled water to remove the dust, microorganism, any particles or other impurities that may be on the leaves. Washed leaves will be weight accurately 20 gm. The weight leaves will be taken in the mortar piston and will be chopped and crushed well. Further, well-minced leaves will be boiled at temperature 70^oC for about 30-35 minutes in 200 ml distilled water. The assembly will consist of the attachment of the condenser with the round bottom flask standing on the rota-mantle with constant stirring. The boiled extract willbecooledandfilteredthroughWhatmanfilterpaper.Thefilteredextractsolutionwill be used for the synthesis of Lanthanides doped MFe_2O_4Nanoparticles.

5.3 Synthesis of Lanthanide-doped MFe_2O_4 nanoparticles

Synthesis of Yb-doped $MgFe_2O_4$, $CuFe_2O_4$ and $MgCuFe_2O_4$ nanoparticles. The Yb- doped Mg Fe_2O_4,$CuFe_2O_4$, MgCuFe2o4 Nanoparticles will be synthesized by using co- precipitation method. For the synthesis of Yb-doped $MgFe_2O_4$ Nanoparticles, Iron (III) nitrate non a hydrate, Magnisium (II) nitrate hexahydrate, Ytterbium chloride hexahydrate and Copper (II) nitrate trihydrate will be used as precursors. PVP/plant extract will be used as surfactant in the chemical/green synthesis process. For Yb-doping synthesis, firstly 0.1 M of, Iron (III) nitrate non a hydrate will be dissolved in 100 ml of distilled water in which desired molar concentrations (0.02 & 0.02 M) of two paired metal salts will be dissolved in 100 ml of distilled water and further it will be added drop wise for the preparation of Yb-doped MFe_2O_4 aqueous solution with constant stirring on magnetic stirrerat 70^o C temperature . PVP/plant extract will then be dissolved in100 ml of distilled water and will be added to above prepared solution drop by drop.As a last step, 1.5 M of NaOH will be added to the prepared solution. The aqueous solution will be stirred on magnetic stirrer for 7 hours at 80 ^{o}C temperature. The obtained Nanoparticles will be washed several times with distilled water and ethanol. Now, theywill be dried in vacuum oven at 1.5 KPa at 80 ^{o}C temperature for 12-24 hours.After drying in vacuum oven, Yb- doped $MgFe_2O_4$, CuFe2O4, MgCuFe2O4 Nanoparticles will be calcinated at 600 ^{o}C temperature for 6 hours.

5.4 Characterization of synthesized Yb-doped MFe_2O_4 Nanoparticles

The synthesized Yb-doped $MgFe_2O_4$, $CuFe_2O_4$, $MgCuFe_2O_4$ Nanoparticles will be characterized to determine its various physical as well as chemical properties such as crystallite size, crystal structure, lattice parameters, crystal phase, bandgap, functional groups, surface morphology, particle size and also magnetic properties. The characterization techniques will be used for determining these parameters are X-ray diffraction (XRD), UV-visible spectroscopy, Fourier transform infrared spectroscopy (FTIR), Scanning electron microscope (SEM), Transmission electron microscope (TEM) and Vibrating-sample magnetometer (VSM).

5.6 Photocatalytic activity

In this study, experiments will be performed to evaluate the photocatalytic properties of synthesized Lanthanides-doped MFe_2O_4 Nanoparticles by photocatalytic degradation of commercial dye. The photocatalytic decomposition of dyes will be examined by measuring the absorbance at regular time intervals by using UV-Visible spectrophotometer.

To evaluate the photocatalytic activity of the synthesized Nanoparticles in degrading metal ferrite, 100 mL aqueous solutions containing 10 ppm of each dye will be used (Xionget al., 2017). Different amounts of synthesized nanoparticles will be added to the solutions. The solutions will be stirred on a magnetic stirrer in the dark for few minutes. After this dark adsorption period, 5mL of the solution will be withdrawn and labelled as the "0 min" sample. The remaining solution will be exposed to UV light illumination using a 125 W mercury vapor lamp, with photocatalyst. The degradation of the dyes will be monitored at regular interval until the synthesizes. Nanoparticles degraded. UV-visible spectrophotometry will be employed to track the decomposition of the dyes by measuring the changes in absorbance. After completing the reaction, the percentage degradation will be calculated using a specific equation (Aet al., 2020; Balouiri et al., 2016).

$$\%\text{Degradation}=(A0–At)x100\ /A0$$

Where Ao represents the absorbance of the pure dye solution and At represents the absorbance of the reaction mixture at time t.

5.7 Antioxidant activity

Antioxidant activity of Lanthanides (Yb, Nb, Gd, Er) doped MFe_2O_4(M=Mg, Cu, Zn, Ti, Si, Mn, Co, Ni) Nanoparticles will be performed with the help of DPPH assay, a stock solution of DPPH (0.1Mm) in methanol will be prepared and will be kept in dark to avoid degradation. Next, a series of nanoparticle suspensions with varying concentrations will be prepared by dispersing the nanoparticles in methanol. Each suspension (1 mL) will be then mixed with 2 mL of the DPPH solution. The reaction mixtures will or texed thoroughly and incubated in the dark at room temperature for 30 minutes to allow sufficient interaction between the nanoparticles and the DPPH radicals. The absorbance of each mixture will be measured at517 nm using a UV-Vis spectrophotometer. A control sample, containing DPPH solution without nanoparticles, will be used for reference. The percentage of DPPH radical scavenging activity will be calculated using the following equation (2):

$$\%\ Scavenging=\frac{Absorbance of control-Absorbance of sample}{Absorbance of control}\times 100$$

6. Thesis Outline

The thesis will be comprised of following chapters:

Chapter 1 (Introduction): It will constitute of the brief account about nanoparticles and nanotechnology. This chapter will also include ferrites their properties and types. Thuja plant, its characteristics and applications will also be explained in this chapter. It will also include the objectives of proposed study.

Chapter 2 (Literature Review): This chapter will deal with intense literature with context to the synthesis, characterization and applications of MFe_2O_4 Nanoparticles. It will also include the research gap identification.

Chapter 3 (Materials and Methods): This chapter will comprise the detail of materials, chemical as well as green synthesis, characterization techniques and applications of Lanthanides-doped MFe_2O_4 Nanoparticles.

Chapter 4 (Results and Discussions): This chapter will include different results and analysis obtained from different characterizations and comparison of findings of work

Chapter 5 (summary and conclusions): It will include the summary and conclusion of averall work done keeping in view different objectives.

Chapter 6 (References): This will include references which will be strictly according to the Harvard style.

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CERTIFICATE
(SYNOPSIS APPROVAL CERTIFICATE)

This is to certify that the Synopsis for Ph.D. Thesis titled, **"A STUDY OF GREEN SYNTHESIZED LANTHENIDES-DOPED SPINEL FERRITE (MFe_2O_4) FOR PHOTOCATALYTIC AND ANTIOXIDANT ACTIVITIES"** submitted by **Ms. Nisha Devi** to the Career Point University, Hamirpur (H.P.), India in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in the Department of Physics, School of Basic &Applied Sciences has been approved by the Research Advisory Committee (RAC) after an Oral Examination of the student on dated 26.12.2023.

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